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What Can Growth Rates Tell Us? A Short-Run Decomposition Method

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Abstract

Consider time series output data for two sectors, industry and agriculture. By examining just the output data themselves, what can we say about the relative impact of institutional/policy factors, intrasectoral competition for resources, and intersectoral linkages on each sector's growth? Currently the answer might be very little. Our aim is to fill this gap: First, we explain how institutional/policy and other factors can be formally derived from a growth rate term. Second, we offer an empirical illustration of the derivation, such that just the time series output data of the two sectors *by themselves* contain enough information to make inferences regarding the relative impacts of the institutional/policy and other factors. Thus we provide the formal decomposition of a growth rate term, allowing the relative impacts of key explanatory variables to be estimated from a highly parsimonious data set. For countries that publish limited data sets, our method extends the ability of researchers to make inferences about the impact of institutions and so on, even when data on institutions are unavailable.

Keywords

short-run growth
growth decomposition
institutions and policies
China

JEL Codes

O43, P30, C13

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1. Introduction

Recent discussions of economic growth have shifted from exploring long-run, mean determinants, where capital and technology have assumed pivotal roles, to investigating abrupt changes in the short-run. Pritchett (2000) notes that a single time trend fails to adequately explain the path of per capita GDP in most developing countries, given that variability in a country's growth rate over time may be very large. Yet economic development benefits from sustained, stable growth – the large economic growth literature that has focused on mean growth has mainly ignored growth rate volatility and therefore the factors that may undermine people's living standards (Mobarak 2005). Thus, research into what initiates or ends episodes of growth is likely to have high payoffs (Pritchett 2000). This point is no more stark than in the reform experience of perhaps the most important developing country today – China. Even the last 20 or so years have seen far-reaching swings in China's political and economic institutions that influence growth episodes, as well as huge transfers of labor as the rules of the game have changed. These swings have resulted in growth rate changes within important sectors such as industry. Yet little research has been undertaken to answer key questions such as: Has China's industrial output growth episodes arisen more from changes in institutional factors, from changes in resource constraints, or from linkages with other sectors, such as agriculture, that themselves exhibit growth volatitily? For policy purposes the answer to this question is crucial, especially if we are to learn from the Chinese experience.

To address these questions we must turn to data. Yet an extensive examination of China's sources, such as statistical yearbooks, reveals data on standard inputs and outputs, but nothing on the strength of institutional and policy settings. Thus, researchers and policy-makers on China (and similar developing economies) face a common obstacle: if institutions seem important and volatile, but data on their impacts cannot be readily found, how can they really know that institutions matter? Past studies in this regard have invoked additional, complex steps. Kwan and Chow (1996) build an econometric model of growth in the Chinese economy to include major political shocks. When the shocks are removed, the hypothetical paths of the economy are derived from the model; comparing them with the actual time paths reveals the impact of adverse political institutions. But such an approach lends itself to large, discrete shocks. In contrast, reforming developing economies may be subject to numerous, continual institutional/policy changes of varying magnitude. Coping with shocks of this nature makes onerous demands on the data, especially if alternatively they are modelled as dummies in the regressions. Employing proxy variables may be useful, but such data are not always at hand.

Still, time series output of industry and agriculture are readily available. By examining just the output data themselves, could they shed much light on the relative influence of institutional factors, resource constraints and agricultural linkages to industry's growth, for instance? We suggest a method by which this can be achieved, focusing on the algebraic definition of a (short-run) growth rate itself. Our aim is twofold: first, to explain how institutional, resource and other factors can be formally derived from a growth rate term; i.e., embedded into a single growth rate equation. Second, we will offer an empirical illustration of the embedding, such that the output data of the two sectors *solely by themselves* contain enough information to make inferences regarding the relative impacts of the institutional factors, resource constraints, and intersectoral linkages. This point is important, given the limited data availability that researchers and policy-makers in developing countries often face. As will become apparent, our two aims are connected – the specific, formal structure of the growth rate term to be developed is precisely that which will facilitate the extraction of information about the relative role of institutions and so on from a very limited data set.

In this paper we use official Chinese data to illustrate how the informational content of limited, publicly available data can be extended. We do believe that there are data manipulations in official data, but this is beyond our scope – the point is to reveal how standard data can offer more empirical insights than hitherto might have been expected.

Basic Premises

The key to understanding our approach is to consider the implications of a statement such as: 'the growth rate of industry is 14.4%'. If *M* represents industrial (or manufacturing) output, the statement is equivalent to the expression:

$$\frac{dM(t)\big/dt}{M(t)} = 0.144$$

$$\Rightarrow \frac{dM(t)}{dt} = 0.144M(t).$$

The growth rate statement can thus be interpreted as a differential equation, where the coefficient on *M* (the 0.144) can be thought of as a variable that may change independently of *M*. For example, exogenous changes in political or economic institutions may alter industry's per unit growth rate, *r* (to be defined later), where:

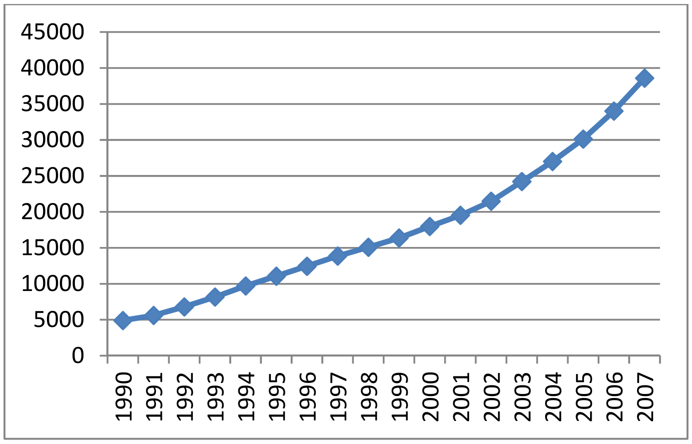
$$\frac{dM(t)}{dt} = rM(t). \qquad \text{(i)}$$

It is the formal construction of *r*, incorporating the broad categories of labor and non-labor institutions and policy, together with intersectoral linkages, that forms the basis of what follows.

To inform our modeling, we seek insights from actual data and events - in our illustrative case, from China. A number of significant *stylized facts* emerge from the Chinese economic literature and data. First, we note that industrial output for our sample period 1990-2007 hint at exponential, or more likely logistic, growth (Figure 1). The suggestion of logistic growth should come as little surprise. Aoki and Yoshikawa (2002) highlight the ubiquity of logistic growth functions, as a stylized fact, in industry as a whole and in specific industries within the sector. Growth may initially be exponential, but as economic activity consumes available resources, a physical limit to the number of firms that may exist and compete in the sector is approached, with the growth rate declining and eventually tending to zero.

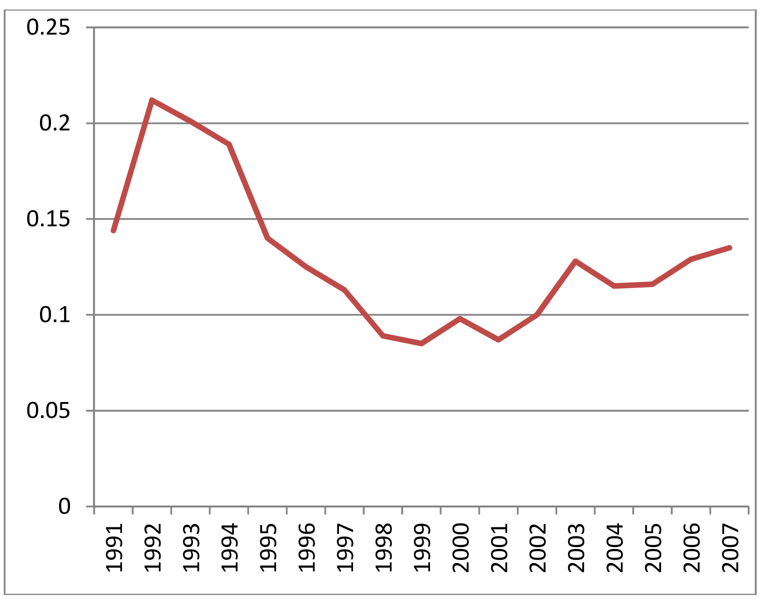
Employing similar logistic functions to formalize economic growth has been undertaken elsewhere in the literature. Clark *et al.* (1993) use logistic functions to model the share of manufacturing value added in GDP over time, as do Balance *et al.* (1982). Day (1982) posits a neoclassical one-sector model with a production function given by $y = Bk^{\beta}(m-k)^{\gamma}$, where y is output, k is the capital/labor ratio and m, B, β and γ are parameters. It is this modelling tradition that we follow. For our empirical work, we will modify Day's (1982) production function to give output of the industrial sector. Instead of a capital/labor ratio, we focus on a single input, labor, and will incorporate simple linkages with agriculture, given the stylized facts below.

Figure 1: Industrial Value Added, China, 1990-2007



The data appear in the appendix, and are expressed in 100m yuan in 1978 prices.[1] Secondly, the data series exhibits growth volatility. Figure 2 shows the growth rates of industry over the sample period.

Figure 2: Annual Industrial Growth Rates, 1991-2007



[1] Note that the data may exhibit shifts in the growth function, as explained later.

Lastly, between 1990-2007, the growth rate fluctuations have come from three main sources. First, frequent and dramatic changes in institutions/policies have been evident (see Wu, 2010). Among others, these include the post-1989 political purges, Deng Xiaoping's call in 1992 for bolder reform, the 1995 campaign to control the overheating economy, responses to the Asian financial crisis of 1997-98, accession to the WTO in 2002 (Zheng, Bigsten and Hu, 2007), economic and administrative measures in 2004-2006 to counter the investment boom (Krueger 2005), and the 2007 anti-corruption drive. According to Klenow (2001), '(g)rowth miracles are produced by dramatic improvements in policies, and growth disasters by deteriorating policies. China is a fast grower...because it has improved its institutions so much' (p. 222).

Secondly, while increases in capital and technology are likely to have contributed to increased industrial output over time, they are not likely to responsible for the year-to-year volatility in growth rates. As Easterly and Levine (2001) point out, again as a stylized fact, '(g)rowth is not persistent over time, but capital accumulation is' – i.e., changes in the capital stock are not closely correlated with changes in economic growth (p. 179). In China the short-run volatility has come from fluctuations in labor supply to industry, as the government has either restricted labor flows or permitted rural unemployed labor to migrate to industry (i.e., via changes in institutions or policy). Kroeber (2005) suggests that the most important contributor to China's impressive economic growth has been the shift of labor from agriculture to industry.

Thus, in our later modeling, we will separate the impact of institutions/policy into two broad categories: non-labor and labor. Non-labor institutions and policy, for example, include those that impact on incentives to reinvest profits in the creation of new firms. They might also affect capital and technology, such as policies that facilitate 'catch-up growth' driven by adopting technologies and organizational innovations from overseas, but in our later modeling we focus on labor as the key input in production. Due to the singular importance of labor, we split off institutions and policies to those specifically influencing labor flows, such as migration regulations and so on.

Third, of the two sectors, agriculture and services, that could conceivably influence volatility in industrial growth, the most important one is agriculture.[2] This follows the standard development literature, in which agriculture either contributes to or competes with the growth of industry (e.g., see Mellor (1986)) or releases labor to it (Gollin et al. (2002)) in relatively early stages of development as intersectoral linkages are established. Note also that in Gollin et al. (2002) agricultural output is produced only by labor.

These stylized facts will inform our construction of a growth rate equation for industry. Hence, our work using China as a case study fits strongly within the important, emerging literature on short-run growth instability in developing countries. In this literature, growth instability has been shown to be strongly linked with changes in political leadership, particularly in autocratic countries (Jones and Olken 2005). Political institutions matter (Mobarak (2005). Jerzmanowski (2006) highlights the relationship between growth and the

[2] As we explain in the empirical section, services drop out of the regressions. Thus, to keep the formal model simple, we focus only on a two-sector model. A three-sector model incorporating services is nonetheless straightforward to construct, and may well be important for countries at later stages of growth, where wholesale and retail trade, business services, education, health, and so on may have significant impacts.

quality of economic institutions, including the rule of law and the protection of property rights. Institutions affect the interactions between economic shocks and growth rates, and the likelihood and duration of high growth episodes. A mixture of political and economic institutions may be captured by special groups, resulting in extractive, economically distortionary policies that lead to growth instability and downturns (Acemoglu et al. 2003). Jones and Olken (2008) find that monetary instability influences growth collapses. More broadly, Hausmann, Pritchett and Rodrik (2005) include economic reforms as a significant contributor to sustained growth accelerations. The foregoing may be broadly categorized as institutional factors (political or economic) impacting on short-run growth, many of which affect incentives to produce. For our purposes we define institutions as the rules of the game that influence the size of profit and the willingness to reinvest profit.

Institutional change not only affects incentives, but can release resources from one sector to another. China's stop-go economy of the 1990s illustrates this point dramatically. Labor supply fluctuations resulting from swings in economic or political institutions, because of their importance, should be included explicitly as a second broad category influencing short-run growth. This is especially relevant for developing economies, like China, that rely to a large extent on labor-intensive production processes. Institutional changes such as permitting labor to migrate to industry reduce intra-sectoral competition and increase growth rates - fluctuations in labor market institutions can translate into growth rate changes.

Mobarak (2005) also identifies a sectoral shift from agriculture to manufacturing in searching for *a priori* determinants of a growth takeoff. The interactions between the sectors introduce additional empirical insights, since the sectoral composition of an economy is important for economic growth rates (Echevarria 1997). We treat the interaction between agriculture and industry as the third determinant of growth rates.

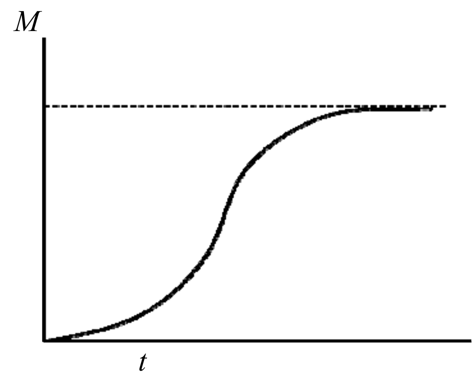
Individually, the papers cited above yield important insights into the determinants of short-run growth. But collectively there is currently no framework that unifies the disparate growth determinants or allows their relative importance to be measured. As mentioned earlier, we need to ascertain how important intersectoral linkages have been in explaining the growth of industry, relative to the incentives to reinvest in industry that have been unleashed by institutional/policy changes in that sector, including the role that intrasectoral competition for labor, labor migration and controls thereof have had.

2. Decomposing a Per Unit Growth Rate

We emphasize at the outset that it is not our aim to formalize a theory of how institutions affect incentives. Nor do we offer a new model of economic growth or a story of total factor productivity. Rather our objective is to show how a sectoral growth rate can be decomposed into the contribution of institutions, including those that impact on labor constraints, and intersectoral linkages. This enables us to determine the empirical contributions of these factors using very limited data. That is, consistent with the stylized facts in the previous section, we seek a fuller expression for r in equation (i).

To this end, the stylized facts inform the structure of our model. While it is apparent that there is exponential growth in manufacturing output in Figure 1, there must be an upper limit to manufacturing output implied by resource constraints (Aoki and Yoshikawa, 2002). This suggests a logistic curve as the eventual form of Figure 1, as illustrated in Figure 3.

Figure 3: Logistic Growth of Manufacturing (hypothetical)



The logistic equation (Figure 3) is given by:

$$\frac{dM}{dt} = r_M\left(1 - \frac{M}{K_M}\right)M.$$

where r_M is the 'intrinsic' growth rate, defined as the growth rate at which M would grow without the inhibiting effects of resource scarcity. Resource scarcity is introduced via the term K_M, the upper limit to manufacturing output defined by existing resources in the sector. More specifically, $-M/K_M$ indicates intra-sectoral competition. Increasing M may lead to greater competition for fixed resources, such that the per unit growth rate of industry, $r_M\left(1 - \frac{M}{K_M}\right)M$. falls. Hence, our search for r leads us to consider $r = r_M\left(1 - \frac{M}{K_M}\right)$,. where r may be decomposed into two distinct terms: the intrinsic growth rate, r_M, and the impact of resource constraints, $-r_M M/K_M$, that also determine r.

To establish the microfoundations of the logistic equation, we begin with a one-sector model of economic growth, that of industry. We could define M as the size of industry, either as measured output or, if firms are assumed to be identical, as the number of firms. To enhance the intuitive value of what follows, we take M as the number of identical firms within industry. Let $C(q, M)$ be the cost per unit of a firm's output, q, when the number of firms in industry is M. Let $R(q, M)$ be the firm's revenue per unit of output. Total profit of a firm is $\pi(q, M) = (R\text{-}C)q$. If profits facilitate growth in the number of firms, the growth rate of M is:

$$\frac{dM}{dt} = \beta\pi(q, M)M. \tag{ii}$$

β is the proportion of profits that are used for reinvestment in creating new firms divided by the amount of profits that are needed to create a new firm. Here we have a preliminary link with Hausmann, Pritchett and Rodrik (2005), Jerzmanowski (2006), Acemoglu et al. (2003) and others, where economic policy and the political environment influence the willingness of firms to reinvest. These institutions relate, for example, to property rights, tax regimes, and so on. Institutions affect profits, π, through changes in prices (such as from trade and investment liberalization) and costs (such as through deregulation). They also operate through incentives to reinvest profits, β, through tax regimes, property rights, etc). Note that these are non-labor-related institutions; later we introduce a separate role for institutions that impact specifically on labor flows.

We give (ii) a more concrete form, now emphasizing the role of institutions on resource flows, by deriving a specific cost function. First, assume that a firm's output is a function only of its labor, *l*. Here we follow the short-run growth literature, which typically omits the role of technological change and capital accumulation in growth instability. But we extend the literature by allowing labor to impact on growth rates, for the reasons outlined above. Let the number of workers required to give output *q* be given by an inverse function:

$$l = f^{-1}(q) = g(q).$$

Hence unit cost is:

$$C(q) = \frac{wg(q)}{q},$$

where *w* is the wage rate. Assume that this unit cost has some minimum when quantity $q=q^*$, the competitive equilibrium for the firm. Assume further that the total number of people able and prepared to work in the sector is:

$$lM = aw,$$

where *a* is a constant relating to labor institutions, determined initially by government administrative mechanisms that relax or constrain workers' ability to work in the manufacturing given sector (for example by influencing labor migration flows) and subsequently by the work-leisure choice of the workers that have been permitted to work in manufacturing. Hence, labor is proportional to the prevailing wage rate, *w*, and *w* is positively related to *M*.

At $q=q^*$:

$$g(q^*)M = aw.$$

Now take the first three terms of the Taylor expansion of *C*(*q*) near q^*:

$$C(q) \approx C(q^*) + C'(q^*)(q-q^*) + \frac{C''(q^*)}{2}(q-q^*)^2.$$

Noting that since q^* is the competitive equilibrium for the firm, $C'(q^*) = 0$:

$$C(q) \approx \frac{wg(q^*)}{q^*} + \frac{C''(q^*)}{2}(q-q^*)^2$$

$$= \frac{C''(q^*)}{2}(q-q^*)^2 + \frac{g(q^*)^2}{aq^*}M$$

$$= \gamma(q-q^*)^2 + \phi M, \qquad \text{(iii)}$$

where the constants of the unit cost equation are $\gamma = C''(q^*)/2$ and $\phi = g(q^*)^2 / aq^*$. The term ϕM represents additional costs proportional to the size of the sector, where increases in the number of firms, M, drive up resource costs. Note, however, that if increases in the number of industrial firms leads wage costs to fall for each firm, for example due to pecuniary externalities in organizing labor transfers to industry, then the sign on ϕM will be negative.[3] In this case, intrasectoral competition for resources will be offset by the pecuniary gains from cheaper access to labor – i.e. the labor constraint is relaxed as M increases, raising the growth rate of industry. Note also that the size of M is ultimately determined by economic policy.

Assume that the price of manufactured goods, p, decreases linearly with M, such that $p = p_0 - \alpha M$, where α is a positive constant. Thus, profit per firm is given by:

$$\pi = (p_0 - \alpha M - \gamma(q - q^*)^2 - \phi M)q. \tag{iv}$$

From (ii):

$$\frac{dM}{dt} = \beta q(p_0 - \alpha M - \gamma(q - q^*)^2 - \phi M)M. \tag{v}$$

We can think of $\beta q(p_0 - \alpha M - \gamma(q - q^*)^2 - \phi M)$ as the individual firm's contribution to the growth rate of M, ie, as a per unit growth rate. Defining the constants $r_M = \beta q(p_0 - \gamma(q - q^*)^2)$ and $K_M = (p_0 - \gamma(q - q^*)^2)/(\alpha + \phi)$, and with the dot indicating the time derivative, we have (Turner and Rapport 1974):

$$\dot{M} = (r_M - \frac{r_M}{K_M} M)M \tag{vi}$$

$$= r_M(1 - \frac{M}{K_M})M, \quad \text{as suggested above.}$$

Equation (vi) represents a simple logistic model describing the growth in the number of firms in industry, as suggested by the first stylized fact in the previous section. The bracketed term is the per unit growth rate, and, as defined above, relates to the impact of institutions in inducing firms to convert profits into the creation of new firms. r_M does not contain the term □M; therefore it excludes a, the constant reflecting institutions that govern labor supply. Thus r_M may be thought of as representing non-labor institutions, such as political stability, property rights allocation, operational autonomy, and other incentives to reinvest profits into firms. We also note the role of international trade in explaining growth accelerations (eg, see Jones and Olken (2008)), here potentially acting through prices, costs and output levels.

Now consider the second term in brackets, ($r_M M/K_M$). Define K_M as the maximum number of firms that labor resources in the sector may support indefinitely. As M approaches

[3] Thus in equation (vi), the sign on ($r_M M/K_M$) will be positive.

K_M, the per unit growth rate tends to zero. Thus, we can think of ($r_M M/K_M$) as the impact of resource scarcity on the per unit growth rate. To see why K_M is the limit to the number of firms that may exist, consider equation (v). For dM/dt to equal zero, i.e., there is no further growth in the number of firms, it is sufficient that $p_0 - \alpha M - \gamma(q-q^*)^2 - \phi M = 0$. In other words, $M = (p_0 - \gamma(q-q^*)^2 / (\alpha+\phi) \equiv K_M$. (And in (v), when $M = K_M$, dM/dt = 0.) Thus we have introduced intrasectoral competition to the model, i.e., the competition for labor between firms within industry. Note that K_M may change over time if the parameters determining K_M change. For example, from $K_M = (p_0 - \gamma(q-q^*)^2 / (\alpha+\phi)$ and $\phi = g(q^*)^2 / aq^*$, an increase in a, a determinant of labor supply, raises K_M and reduces the growth-inhibiting effect of intrasectoral competition between firms. If p_0, γ, q^* and α are all constant, then K_M varies only with a. That is, labor supply determines K_M. Thus, we have derived a labor constraint determinant of growth volatility. Recalling that a relates to government policies relaxing or constraining workers' ability to work in a sector, we have a term that reflects administrative interventions in labor markets.

The term r_M plays two roles. In the absence of resource scarcity, r_M increases the overall growth of M exponentially; but as M grows, for a fixed K_M, it is the very increase in M, and the attendant competition for resources, that reduces growth as M approaches K_M. K_M is the size of the manufacturing sector where r_M is cancelled by intrasectoral resource competition. But a change in labor-related institutions, α, can raise the growth rate by raising K_M; ie, by shifting the logistic curve upwards. In other words, an increase in K_M increases the slope of the M function, and thus raises the per unit growth rate at any given value of t by an amount $r_M M/K_M'$. It is in this sense that we claim that the term $r_M M/K_M$ partially reflects the impact of changes in labor supply institutions on growth rates.[4] If we see empirically that the intrasectoral competition coefficient falls over time, this is evidence of labor inflows, raising K_M, that have swamped the growth-inhibiting effect of competition for labor between industrial firms.[5] Note that we have assumed that ϕM is positive, in line with logistic growth, but ultimately the sign of $r_M M/K_M$ will be determined empirically.

Now also suppose that agricultural output influences the growth rate of manufacturing firms (Mobarak 2005), initially by assisting manufacturing to expand beyond its normal carrying capacity. Firms not only compete for factors of production within their sector, but may compete with, or contribute to, firms outside their sector. Models of structural change, such as in Mellor (1986), incorporate a system of intersectoral linkages. The linkages come about for a variety of reasons: one sector pays factor incomes, which consumers use to purchase the other sector's goods; one sector produces intermediate goods and services used by other sectors; and so on.

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[4] A simple numerical example illustrates the point. Suppose r_M = 0.5, M = 1, K_M = 100; then the per unit growth rate is 0.495. If K_M' = 200, then the growth rate is 0.4975. The growth rate increases by 0.0025 (= $r_M M/K_M'$).

[5] In the Chinese illustration that follows, we focus on labor flows. In a more general framework the parameter a could be influenced by other factors, such as capital and technology, that raise the number of firms that the industrial sector could support (i.e., the carrying capacity).

Here we consider the case, prevalent in developing countries undergoing structural transformation, where agriculture competes with industry leading to higher input and factor prices for manufacturing. That is:

$$C(q) = \frac{wg(q) + \varepsilon A}{q}$$

$$\approx \frac{wg(q^*) + \varepsilon A}{q^*} + \frac{C''(q^*)}{2}(q - q^*)^2$$

$$= \frac{C''(q^*)}{2}(q - q^*)^2 + \frac{g(q^*)^2}{aq^*}M + \frac{\varepsilon A}{q^*}$$

$$= \gamma(q - q^*)^2 + \phi M + \frac{\varepsilon A}{q^*}$$

The cost function for industry can now be rewritten:

$$C(q, M, A) = \gamma(q - q^*)^2 + \phi M + \kappa A, \qquad \text{(vii)}$$

where $\kappa = \frac{\varepsilon}{q^*}$

Thus, equation (v) becomes:

$$\frac{dM}{dt} = \beta q(p_0 - \alpha M - \gamma(q - q^*) - \phi M - \kappa A)M$$

$$= (r_M - \frac{r_M}{K_M}M - \delta A)M, \qquad \text{(viii)}$$

where $\delta = r_M \tau$ and τ is a constant. If δ is negative, as shown in (viii) agriculture competes with manufacturing; a positive δ would indicate a supportive relationship between the two sectors. Ultimately the sign must be determined empirically.

Again, we can think of the term $(r_M - \frac{r_M}{K_M}M - \delta A)$, or $r_M(1 - M/K_M - \tau A)$, as a per unit growth rate. It is the comparison of the size of each term in the per unit growth rate that reveals the relative contributions of institutions (labor and non-labor) and that of agriculture-manufacturing linkages to manufacturing growth rates.

Finally:

$$\frac{\dot{M}}{M} = r_M - \frac{r_M}{K_M}M - \delta A. \qquad \text{(ix)}$$

Equation (ix) models the growth rate of manufacturing as depending on the intrinsic growth rate, r_M, which captures institutional determinants of the sector's growth (via incentives for firms to invest their profits in the production of new firms); on competition between firms for labor (at the sectoral level); and on the impact of another sector, agriculture (an intersectoral effect). The model is flexible enough to encompass aspects of international trade (through the impact of changing demand and supply on prices), and political and economic institutions, such as a kleptocracy and property rights (that affect the proportion of profits that becomes new firms each period, β.)

The differential equation explains the growth rate of the sector in terms of its present size and the size of the other sector. The sector initially grows exponentially, but its growth slows under increasing intrasectoral competition, eventually falling to zero. While it may seem intuitively obvious that the growth rate of manufacturing will depend, at least, on institutions, labor supply and the linkages with agriculture, our pursuit of a formal model offers a very significant advantage. Concretely, the (per unit) growth rates include the variables M and A (the RHS of equation (ix)). This allows empirical estimation to proceed with minimal data requirements, as will be explained in the next section.

3. An Illustration

Our theoretical derivation of a growth rate lends itself to empirical analysis with parsimonious data requirements. We demonstrate how a time series solely comprising agricultural and manufacturing value added, for example, can yield insights into the impacts of institutional factors, market competition for resources, and intersectoral linkages in explaining the growth rates of the two sectors.

We illustrate our model with a case study of China. The Chinese reforms in agriculture and industry offer a potentially rich dataset that reflects the impacts of institutional change and autocratic policy-making (eg., Islam and Jin (1994), Woo, Hsueh, Shi and Zhang (1993), Zweig (1992), Sicular (1992), Wu (1992), Findlay and Watson (1992), Islam (1991)), interactions between the agriculture and manufacturing (B. Lin (1995), Findlay, Watson and Wu (1994), and intrasectoral competition for resources (Islam and Jin, 1994).

While the theoretical derivation expressed the size of each sector as the number of identical firms, this is not an appropriate interpretation for empirical testing. The main problem is the lack of reliable and consistent Chinese data on firms, both industrial and agricultural. A way to resolve the problem of defining the 'size' of each sector is to take M and A as outputs, value-added, total assets or employment. Since sector profit is proportional to size, in our regression we choose value-added over the other measures. Data are taken from the National Bureau of Statistics (2009). The data provided in the Statistical Yearbook of China have been used in landmark studies of Chinese economic growth, e.g., Kwan and Chow (1996). Examining the data in the Appendix reveals an interesting divergence in growth - real industrial value added increased almost eight-fold over the sample period, while agricultural output only doubled.

In terms of estimating the relative contributions of institutions and agricultural competition to industry's per unit growth rate, take equation (ix) as an example. The left hand side is the annual fractional change in real manufacturing output. Regressing this on M and A, the coefficients will be r_M/K_M (relating to intrasectoral competition for labor) and δ

(relating to the intersectoral impact between agriculture and industry), respectively, with the constant equivalent to the intrinsic rate of growth, r_M, relating to non-labor-related institutions and policies.

The constant in the regression could be a 'black box', but the key to thinking about it is to consider the causes of growth volatility, not the level of output. Output levels could depend on many things, including institutions, capital, technology, scale, externalities, labor supply, and so on. But we are examining only a subset of these – those that vary enough to shock growth rates on a year-to-year basis. This rules out technology, capital (as discussed earlier), scale, and externalities, leaving only economic and political institutions, the policies that result from them.

A clear problem is that the variables in the formal model are instantaneous quantities, whereas the available data is annual. The growth rates refer to the growth over a given calendar year, and the values added/outputs of the sectors are available at the beginning and end of this interval. It seems logical to take the mean (or some other weighted average) of the terminal points, but all variables in the above regressions turn out to be insignificant. Using the initial points (in fact, the lag of value added/output, since the corresponding initial output for growth in 1991 is the output at the end of 1990) yields better results:

Dependent variable, $\frac{\dot{M}}{M}$, using total industrial value-added, 1991-2007

Model: OLS[6]

	Coefficient	*t*-ratio
Const	0.640982	6.350 ***
A (lagged)	-0.0002701	-5.228 ***
M (lagged)	0.00001806	5.196 ***

*** 1% significance; *R*-squared 0.68; Durbin-Watson 1.88

Quandt likelihood ratio tests suggest no structural breaks in either manufacturing or agriculture in the sample period. Tests on a wider sample (1979-2007) indicate a structural break in industrial value added in 1990; thus, we restrict our sample to 1991 onwards.

In the 1991-2007 sample period, total industry exhibits an r_M of 0.641. r_M/K_M is positive at 0.00001806, indicating no firm evidence of intrasectoral competition or logistic growth during the sample period (the positive sign suggests that China did not witness a tailing-off in industrial growth). A positive coefficient means that manufacturing appears to be experiencing exponential growth without an apparent upper limit. That fits with our knowledge of China's manufacturing growth over that period, which did not show signs of slowing from the early 1990s to the mid-2000s. Intrasectoral resource competition may be hard to detect in the early stages of growth because it is overwhelmed by the exponential

[6] ADF tests were undertaken, where the null hypothesis of a unit root is rejected at the 10% level, but not at the 5% level of significance. There is probably not a unit root, but the number of observations may be too small to reject it at the 5% level. The Phillips-Perron test does reject the null of a unit root at the 5% significance level.

growth component. The coefficient determining the relationship between agriculture on industry is negative (δ = –0.0002701). The negative coefficient suggests that agriculture and competed with one another.

In this illustration, to find the contribution of each growth determinant, we now multiply r_M/K_M by the mean of annual manufacturing value added over the period 1991-2007, i.e. by 18351.37, giving a value of 0.331. Similarly, for δ we multiply by mean agricultural output, 3114.293, giving a value of -0.841. Thus, the estimated per unit growth rate has a value of 0.641 + 0.331 - 0.841 = 0.131. This matches the actual average growth rate for industry over the period 1991-2007, which is 13.11 percent.

Over the 1991-2007 period, non-labor institutions appear to have contributed around twice as much as the relaxation of labor constraints to the growth rate of manufacturing, while the adverse impact of agriculture on manufacturing was less than the combined positive impact of institutions and resource constraint relaxation. We also undertook regressions that included a third sector, services, but the variable was statistically insignificant. Granger-causality tests reject the null that agricultural does not Granger-cause industrial output.

Still, a question remains: does our model measure the impact of institutions as claimed? In particular, does the constant in the regression reflect the impact of institutions and policies? To determine the role of our constant, we employ a proxy for institutions/policies in the regression to see how much the constant falls. The proxy we use is agricultural employment.

Figure 3 shows how agricultural employment has responded to institutional and policy changes over time. For example, the initial rise in agricultural employment at the beginning of the series reflects the political swing post-Tiananmen 1989. Deng's tour of Southern China in 1992 resulted in growth of manufacturing, with the privatization of state and collective firms, inflows of foreign direct investment, and acceleration of exports (Zheng *et al.* 2007). But in the face of an overheating economy, economic and administrative counter-measures were introduced to cool investment, reflected in labor shifting back into agriculture.

Figure 3: Agricultural Employment

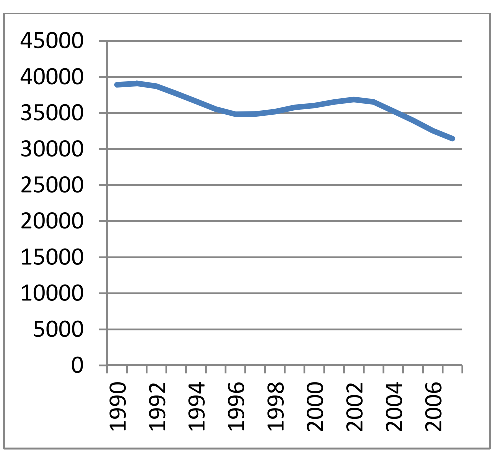
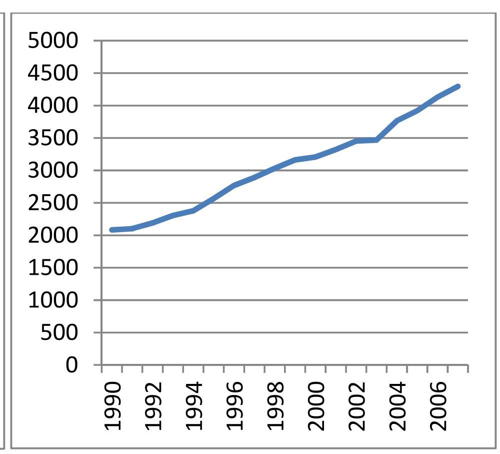


Figure 4: Agricultural Output



We now rerun the above regression with the addition of the policy proxy:

Dependent variable, $\frac{\dot{M}}{M}$, using total industrial value-added, 1991-2007

Model: OLS

	Coefficient	*t*-ratio
Const	0.0078256	0.0305
A (lagged)	-0.0001956	-3.6567***
M (lagged)	0.0000141	3.7996***
N (lagged)	0.0000013	2.5403 **

*** 1% significance; R-squared 0.79; Durbin-Watson 2.01

The correlation coefficient between agricultural employment and agricultural output is -0.82. Agricultural employment thus captures much more than agricultural output. But note that it also captures the impact of labor-related institutions/policies, so it is at best an imperfect proxy for r_M. Still, employing our proxy for institutions/policies has all but removed the constant, providing strong empirical support for the claim that the constant captures institutions and policies.[7]

4. Conclusions

We have provided a method that uses very limited data to extract information about the relative sizes of key factors that influence the growth rates of a sector. We have chosen China to illustrate our method - given the importance of China to the world economy, and the danger of misreading its economic activity, official Chinese statistics are a point of strong interest to businesspeople, policy makers and investors. But the output statistics, by themselves, tend to be looked at superficially. For example, people can see that output may be rising or falling over time. To gain deeper insights more information is typically needed, but the information made publicly available is often limited.

We have demonstrated that simple growth numbers can tell us more than hitherto has been expected. In particular, simple numbers can offer insights about the impact of fundamentals, policies and institutions. Note that, because of our grouping of factors into three broad areas, identification of the key specific factors within each group lies outside the scope of this paper. Our approach obscures further detail that we leave to further research. An example is the labor supply equation that might explicitly model workers' preferences and wages outside the sectors examined. Lastly, for developing countries, on which the short-run growth literature currently focuses, the transition from agriculture to industry justifies our focus on the agricultural sector, rather than services, as a key growth determinant of manufacturing. For more developed countries the impact of the service sector might also be a useful addition.

[7] Multiplying 0.0000013, the coefficient of *N*(lagged), by 362,963, the average value of *N* over the sample period, gives 0.47, which is reasonably close to 0.64, the constant that represents r_M in the first regression.

Appendix: Manufacturing and Agricultural Outputs
(100m yuan, 1978 prices)

Year	Industry	Agriculture
(1990)	(4899.7)	(2083.1)
1991	5605.2	2101.9
1992	6791.2	2190.1
1993	8155.5	2304.0
1994	9698.2	2377.8
1995	11059.4	2565.6
1996	12443.0	2765.7
1997	13850.7	2890.2
1998	15083.3	3031.8
1999	16368.9	3162.2
2000	17971.1	3206.4
2001	19528.3	3321.9
2002	21476.0	3451.4
2003	24214.3	3468.7
2004	27000.8	3763.5
2005	30126.4	3917.8
2006	34005.7	4129.4
2007	38595.3	4294.6

References

Acemoglu, D., Johnson, S., Robinson, J. and Thaicharoen, Y. (2003), Institutional Causes, Macro-economic Symptoms: Volatility, Crisis, and Growth,' Journal of Monetary Economics 50, 49–123.

Aoki, M. and Yoshikawa, H. (2002), Demand saturation-creation and economic growth, Journal of Economic Behavior and Organization, 48 127–154.

Ballance, R., Ansari, J. and Singer, H. (1982), The International Economy and Industrial Development: The Impact of Trade and Investment on the Third World, Totowa, NJ: Allanheld, Osmun Publishers.

Clark, D., Kaserman, D. and Anantanasuwong, D. (1993), A diffusion model of industrial sector growth in developing countries, World Development, 21(2):421-428.

Day, R. (1982), Irregular growth cycles, American Economic Review, 72(3):406-414.

Echevarria, C. (1997), Changes in sectoral composition associated with economic growth, The International Economic Review, 38(2):431-452.

Easterly, W. and Levine, R. (2001), It's not factor accumulation: Stylized facts and growth models, World Bank Economic Review, 15(2):177-219.

Findlay, C. and A. Watson (1992), Surrounding the cities from the countryside, in R. Garnaut and Liu Guoguang (eds.), Economic Reform and Internationalisation: China and the Pacific Region, St Leonard's, NSW: Allen and Unwin.

Findlay, C., A. Watson and H. Wu (1994), Rural enterprises in China, manuscript version, London: Macmillan.

Gollin, D., S. Parente and R. Rogerson (2002), The role of agriculture in development, American Economic Review, 92(2):160-164.

Hausmann, R., Pritchett, L., and Rodrik, D. (2005), Growth accelerations, Journal of Economic Growth, 10(4):303-329

Islam, R. (1991), Growth of Rural Industries in Post-Reform China: Patterns, Determinants and Consequences, Development and Change, 22(4):687-719.

Islam, R. and H. Jin (1994), Rural Industrialization: An Engine of Prosperity in Postreform rural China, World Development, 22(11):1643-1662.

Jerzmanowski, M. (2006), Empirics of hills, plateaus, mountains and plains: A Markov-switching approach to growth, Journal of Development Economics 81, 357-385.

Jones, B. and Olken, B., (2005), Do leaders matter? National leadership and growth since World War II,' Quarterly Journal of Economics 120, 835–864.

Jones, B. and Olken, B. (2008), The anatomy of start-stop growth, The Review of Economics and Statistics 90(3): 582–587.

Klenow, P. (2001), Comment on 'It's not factor accumulation: Stylized facts and growth models,' by William Easterly and Ross Levine, World Bank Economic Review, 15(2):221-224.

Kroeber, A. (2005), China as Employer and Consumer: Economic Outlook for the 11th Five-Year Plan (2006-2010). Conference Paper presented at the China and the World Economy Workshop, December 2005, The Atlantic Council of the United States, Asia Programs.

Kwan, Y. and Chow, G. (1996), Estimating economic effects of political movements in China, Journal of Comparative Economics, 23(2):192-208.

Lin, B. (1995), The Rapid Expansion of Townships and Village Enterprises and Its Impacts on Agricultural Production in China (mimeo), Asian Development Bank.

Mellor, J. (1986), Agriculture on the Road to Industrialization, in J. Lewis and V. Kallab (eds.), Development Strategies Reconsidered, New Brunswick: Transaction Books.

Mobarak, A. (2005), Democracy, volatility, and economic development, The Review of Economics and Statistics 87(2): 348-361.

National Bureau of Statistics of China (2009), China Statistical Yearbook 2009. Hong Kong: International Centre for the Advancement of Science and Technology.

Pritchett, L. (2000), Understanding patterns of economic growth: Searching for hills among plateaus, mountains, and plains, The World Bank Economic Review 14(2):221-250.

Sicular, T. (1992), China's Manufacturing Policy During the Reform Period, in Joint Economic Committee, Congress of the United States (ed.), China's Economic Dilemmas in the 1990s: The Problems of Reforms, Modernization, and Interdependence, NY: M.E. Sharpe.

Turner, J. and D. Rapport (1974), An Economic Model of Population Growth and Competition in Natural Communities, in S. Levin (ed.), Lecture Notes in Biomathematics 2: Mathematical Problems in Biology, Berlin: Springer-Verlag.

Woo, T., T. Hsueh, R. Shi and Y. Zhang (1993), Impact of the Development of China's Rural Non-Manufacturing Sector on the National Economy, in T. Hsueh, Y. Sung and J. Wu (eds.), Studies on Economic Reforms and Development in the People's Republic of China, Hong Kong: The Chinese University Press.

Wu, H. (1992), The Industrialisation of China's Rural Labor Force since the Economic Reform, CERU Working Paper No. 92/6, Adelaide: Chinese Economic Research Unit, University of Adelaide.

Wu, H. (2010), Political incentives and mismatch of Chinese growth rate, Asian Economic Panel Meeting, March 22-23.

Zheng, J., Bigsten, A. and Hu, A. (2007), Can China's growth be sustained? A productivity perspective, World Development, 37(4): 874-888.

Zweig, D. (1992), Rural Industry: Constraining the Leading Growth Sector in China's Economy, in Joint Economic Committee, Congress of the United States (ed.), China's Economic Dilemmas in the 1990s: The Problems of Reforms, Modernization, and Interdependence, NY: M.E. Sharpe.